NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

THE NAVAL POSTGRADUATE SCHOOL
FLIGHT MECHANICS LABORATORY:
A FEASIBILITY STUDY

by

Kenneth S. Reightler, Jr.

December 1984

Thesis Advisor: Donald Layton

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) The Naval Postgraduate School Flight Mechanics Laboratory: A Feasibility Study	5. TYPE OF REPORT & PERIOD COVERED Master's Thesis December 1984
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Kenneth S. Reightler, Jr.	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943	12. REPORT DATE December 1984
	13. NUMBER OF PAGES 46
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Flight mechanics; Laboratory

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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The Naval Postgraduate School Flight Mechanics Laboratory: A Feasibility Study

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
December 1984

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The Naval Postgraduate School (NPS) currently has no laboratory facilities to support the teaching of flight mechanics. This thesis concerns a feasibility study conducted to define the need for a flight mechanics laboratory at NPS, determine the methods used at other universities and availability of resources, develop a plan to integrate laboratory facilities into the NPS aeronautical engineering syllabus, and make recommendations concerning changes needed in the NPS Department of Aeronautics to enhance the teaching of flight mechanics. The general conclusion of the study is that a flight mechanics laboratory is essential to the study of flight mechanics at NPS. The proposed laboratory should include the selective use of flight simulators, computer instructional devices, a flight demonstration airplane, a fully instrumented flying laboratory, and a variable stability airplane. Extensive use should be made of contracted services. A flight mechanics laboratory used to support classroom instruction and research should be established at NPS as soon as possible.

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ACKNOWLEDGEMENTS

I wish to thank Professor Donald M. Layton for his guidance and support as Thesis Advisor. CDR William M. Siegel, Aeronautical Engineering Programs Curricular Officer, provided invaluable assistance and motivation. The faculty and students of the Department of Aeronautics were also helpful in providing ideas, comments and recommendations. The staff of the U. S. Naval Test Pilot School was particularly supportive of this study and gave much assistance in the area of flight simulator development.

Of special note were the support, encouragement and understanding of my wife and children throughout my course of study. My appreciation cannot be fully expressed.

I. INTRODUCTION

A. BACKGROUND

Flight mechanics, including airplane performance, stability, control, and flight test techniques, is widely accepted as a major element of aerospace engineering. The Department of Aeronautics at the Naval Postgraduate School (NPS), because of its close association with Naval Aviation and the large percentage of students who are aviators, has long been committed to the study of flight mechanics.

For many years, this study was facilitated by the presence of the Naval Auxiliary Landing Field, Monterey, California, the airplanes stationed there, and the requirement for Naval Aviators assigned as graduate students to maintain flight proficiency. In addition to the assigned T-28, S-2, and T-33 airplanes, a US-2A airplane, Bureau Number 136533, was modified with flight test instrumentation and used as a flying laboratory [Ref. 1]. Flight simulators, including a Link C-11B variable stability trainer [Ref. 2], were also used to support the teaching of flight mechanics.

When Combat Readiness Training flying for students was discontinued by the Navy in January, 1972, the NPS Department of Aeronautics was forced to rely on commercially leased airplanes to support flight mechanics instruction and research [Ref. 3]. In April, 1973, a Cessna 310H airplane, N164X, was leased for this purpose using funds

provided by the Naval Air Systems Command [Ref. 3]. Development of the flight test instrumentation and airborne data acquisition systems for this airplane resulted in several theses.

Problems associated with funding, reliability of flight assets, and availability of qualified flight instructors caused the airplane leasing program to be terminated after three years. Although flight simulators, including an F-105 cockpit/seat trainer and a F-4 Cockpit Procedures Trainer (CPT), continued to be used for instruction and research, a change in emphasis created an environment in which flight mechanics was considered of lesser importance with no laboratory facilities to support it. A recent restructuring of the Aeronautical Engineering Curricula and renewed interest in the study of flight mechanics prompted this feasibility study to determine the best approach for establishing a flight mechanics laboratory at NPS.

B. GOALS

The goals of this feasibility study were:

1. Define the need for a flight mechanics laboratory at NPS.
2. Determine methods used by other universities and schools to support the teaching of flight mechanics.
3. Determine the availability of resources.
4. Determine the best mix of these resources.

5. Develop a plan to integrate a flight mechanics laboratory into the NPS aeronautical engineering syllabus.

6. Make recommendations concerning changes needed in the NPS Aeronautical Engineering Curricula (610 and 611) to enhance the teaching of flight mechanics.

II. APPROACH OF THE STUDY

A. BASIC APPROACH

The basic approach used during this study involved an analysis of the existing syllabus and laboratory facilities, interviews with faculty members and graduate students, discussions and visits to other universities, liaison with the U.S. Naval Test Pilot School (USNTPS) and U.S. Air Force Test Pilot School (USAFTPS), and meetings with contractors involved with flight mechanics.

B. LIMITATIONS

The limitations and assumptions involved in this study included:

1. The new Aeronautical Engineering Syllabus was assumed to be in effect.
2. No additional courses were to be added to the syllabus.
3. The proposed flight mechanics laboratory was oriented toward fixed-wing airplanes.
4. Every attempt was made to develop cooperative programs with the Naval Air Test Center (NATC) and USNTPS.
5. All contracts, commitments and funding were approved by the Aeronautical Engineering Curricular Officer and the Thesis Advisor.

III. RESULTS

A. NEED

It was the consensus of faculty and students interviewed that laboratory facilities are required to adequately teach flight mechanics at NPS. These facilities would bridge the gap between the theory taught in the classroom and its application. The laboratory would also assist the instructor in teaching the concepts and reinforce these concepts for more complete understanding. The "hands on" experience would not only provide a motivation for learning, but would also make the learning process more enjoyable.

In that the Navy operates several full-time technical aeronautical establishments, including NATC and the Naval Air Development Center (NADC), it is unlikely that the NPS Flight Mechanics Laboratory would receive much direct funding for research. However, many thesis research projects would be created during the development and improvement of the laboratory facilities. Research projects in support of USNTPS and USAFTPS would also be possible because of the common educational mission. The anticipated low cost of the research effort, along with greater accessibility, might prove attractive to other naval activities nearby such as the Pacific Missle Test Center and the Naval Weapons Center, China Lake.

In addition to being an integral part of the general Aeronautics Curriculum (610), the flight mechanics laboratory facilities could also be used to support the NPS Avionics Curriculum (611). An airplane used to demonstrate stability and control concepts could easily be equipped with various sensors and navigation systems and used as an airborne systems laboratory.

An important, but usually unchronicled, aspect of the postgraduate process is the improvement of the technical knowledge of the fleet through education of a few officers. These officers not only use their education in technical shore billets, but will take this knowledge with them to the fleet. This is particularly important in the aviation community, where pilots are taught the techniques and tactics necessary to accomplish their assigned missions, but are rarely given a formal explanation of the flight phenomena they experience daily. Aviators trained as aeronautical engineers and well versed in flight mechanics must be able to provide this training in the fleet, both in ready room lectures and during informal discussions. This level of technical expertise is also critical to other squadron functions such as NATOPS Change Proposals and Aircraft Mishap Boards. The Fleet rightfully expects that graduates of the NPS Department of Aeronautics will have a sound understanding of flight mechanics.

B. METHODS USED ELSEWHERE

During the course of this study, a number of the major universities with aeronautical programs were contacted. Of those, only four were found to have an associated flight laboratory or flight research program: Princeton University, Mississippi State University, Texas A. & M. University, and the U. S. Naval Academy.

Princeton has a long history of research and development in the field of flight mechanics and maintains extensive laboratory facilities. These facilities are used to support the teaching of undergraduate and graduate courses in flight mechanics as well as for research. Recently, however, Princeton has decided to discontinue its flight program and sell all of the associated airplanes and equipment. The Princeton Flight Laboratory could be considered a potential source of assets needed to develop the NPS Flight Mechanics Laboratory.

Mississippi State currently operates the Raspet Flight Research Laboratory (RFRL), which is an integral part of the Department of Aerospace Engineering. RFRL is devoted to research and does not directly support classroom instruction due to university policy. This limitation is primarily the result of insurance limitations and legal liability. It is the opinion of the Department Chairman and the Director of RFRL that such participation would greatly enhance the program. Both men have consistently fought for

approval and funding that would allow the facilities to provide practical demonstrations of theoretical concepts.

The facilities maintained by Texas A. & M. are similar to those of Mississippi State. Texas A. & M. also does not allow students to fly in laboratory airplanes and utilizes its facilities strictly for research.

The U. S. Naval Academy (USNA), although involved strictly in undergraduate education, maintains a flight mechanics laboratory composed of a demonstration airplane and a flight simulator. As opposed to the facilities operated by Mississippi State and Texas A. & M., the USNA laboratory is used almost exclusively to support the various academic courses pertaining to flight mechanics. The flight demonstration airplane used is a Beechcraft Bonanza, leased from Beech Aircraft Corporation, and is instrumented for both flying qualities and performance parameters. Aerospace engineering students are given demonstration flights throughout the four-year syllabus in conjunction with courses in basic aerodynamics, performance, and stability and control. A course in flight test engineering is also offered which makes extensive use of this airplane. Students are required to fly on the data acquisition flights, thus seeing the flight test techniques used, participating in the data recording, and observing first hand some of the problems associated with flight testing. Military instructors from the Aerospace Engineering Department

manage the flight mechanics laboratory and act as demonstration pilots. The contract with Beech has a term of one year and provides for all support, maintenance and insurance. The Academy provides the pilots, fuel and oil, and has been flying approximately 240 hours/year. The fixed cost of the program is $460/month plus a flight cost of $25/hr (Dry), which results in an annual cost of approximately $17,000. The USNA Aerospace Engineering Department is very satisfied with the terms of the contract and the services provided by Beech.

The USNA flight simulator is a Singer-Link Model GAT 1 VS, fixed-base, five-degree-of-freedom trainer. NADC modified the simulator to provide a variable stability capability. Currently, this asset is not being used as a part of the flight mechanics laboratory. A study is now underway to determine how to integrate the simulator into the syllabus.

The course of instruction at both USNTPS and USAFTPS is centered around the study of flight mechanics. The approach used at both schools consists of traditional classroom instruction, ground and flight demonstration of principles and techniques, and finally, simulated flight test exercises. Flight simulators are used to show control system characteristics, stability concepts, control system design considerations, and flight test techniques. Variable stability airplanes, along with the associated

ground and flight instruction, are provided by contractors. These assets are used to demonstrate and reinforce the stability and control theory taught in the classroom. Students are then required to apply the theory and techniques demonstrated to them by conducting flight test exercises involving planning, data collection, data analysis, and report writing. Exercises, briefings, and special lectures are videotaped to be used by students who miss the lectures or as a study aid. The blend of instructional techniques used at these two test pilot schools provides flexibility as well as an increase of the efficiency of the eudcational process. The approach at these schools has been refined over many years and is both successful and cost effective.

The NPS Department of Aeronautics is, for many reasons, unique. Thus, none of the aforementioned programs will fulfill all of its requirements for a flight mechanics laboratory. However, an understanding of the capabilities and limitations of each technique used in the teaching of flight mechanics will facilitate the decisions that must be made concerning the makeup of the laboratory.

C. RECOMMENDED APPROACH

The recommended approach to the NPS Flight Mechanics Laboratory is the selective use of a variety of components. These components should include a flight simulator, computer instructional devices, a demonstration airplane, a fully

instrumented flying laboratory, and a variable stability airplane. Such assets will provide the capabilities necessary to support the teaching of all courses currently offered in flight mechanics, as well as ensure a research capability in this field.

Flight simulators are available today with full motion, six-degrees-of-freedom, sophisticated visual displays, and variable stability systems. However, the cost of such complex devices, along with other requirements such as maintenance and operator training, limit their desirability. Although both visual and motion cues are important in closed-loop piloting tasks, a simulator used for academic purposes could be fixed-base if the proper visual display was incorporated. For the purposes of the NPS Flight Mechanics Laboratory, the simulator display should at least provide a realistic horizon and allow some type of air-to-air tracking task to be performed. A variable stability system will be necessary to show the effect of various parameters, e.g., directional stability, dihedral effect, and adverse yaw. This system should be effective in all three axes and provide the instructor with the capability of quickly and accurately making the desired settings. A memory should also be provided so that the proper sequence of gain settings for each exercise can be stepped through without requiring manual selection. A data recording device will be required to display the desired output

parameters such as sideslip angle, roll rate, or flight velocity. In light of these specific requirements and limited funding, the recommended approach for obtaining a flight simulator is an in-house development. The Department of Aeronautics already has a modified F-4 CPT, Device 2C30, which could provide the necessary cockpit controls and environment. Data recording equipment is available, and one of the Department's microcomputers could be used to solve the equations of motion, drive the visual display, and output the desired parameters. USNTPS has a flight simulator meeting these requirements, and has agreed to provide NPS with technical assistance in this project. The McFadden Corporation has considerable experience in performing special modifications to demonstration flight simulators and should be considered if a sophisticated control feel system is required.

Audio-visual training aids are in wide use and have been clearly shown to improve the quality of instruction. Various techniques are available including slide-tape, videotape, and videodisk. Slide-tape presentations are currently used by the NPS Department of Aeronautics for the Gas Dynamics Laboratory, AE 2814. The videodisk is the newest development in this field, and has rapidly gained popularity. The advantages of the videodisk over other presentations include greater search speed, superior picture quality, and increased data storage. A videodisk

player can be combined with a microcomputer, display and a keyboard to form an interactive computer instructional device. These devices have the capability to present lectures, ask questions on the material covered, respond to correct or incorrect answers, and evaluate student performance. Self-paced, interactive programs could be used to assist classroom lectures or for individual instruction, and would be applicable to every aspect of flight mechanics instruction. The NPS Educational Media Department if currently developing a computer video instructional laboratory to support the use of computer instructional devices. Three work stations, made up of monitors, controllers, players, and microcomputers, have been ordered and should be operating by November, 1984. An authoring system is already available to assist the faculty in developing lectures and presentations. Through a cooperative agreement, the U. S. Army at Ft. Gordon, Georgia, will assist NPS in performing the postproduction and premastering process needed to develop videodisks. The final mastering process is performed commercially at a cost of approximately $3000. It is anticipated that Ft. Gordon will soon have this capability as well, which would virtually eliminate the NPS cost of producing videodisk presentations. Because the Department of Aeronautics already has monitors, computers, and a videodisk player, a controller is all that would be necessary to provide a

computer learning center. Equipment similar to that used by the Educational Media Department is recommended to ensure compatibility, software support, and technical assistance from the computer video instructional laboratory technicians.

A flight demonstration airplane is essential to obtain practical knowledge in the application of aeronautics theory and principles. The airplane needed to meet the requirements of the NPS Flight Mechanics Laboratory is a twin engine, single piloted, cabin class craft with dual controls, seating for two pilots and at least two observers, and rated at less than 12,500 lbs. Limited special instrumentation would be required, but a growth potential is necessary to meet future requirements such as flight test instrumentation, data acquisition packages, or a variable stability system. Probably the most advantageous arrangement to obtain and operate the demonstration airplane is by lease, similar to the contract USNA has with Beech Aircraft Company. A lease avoids the problems associated with procurement of airplanes by government agencies, relieves NPS of maintenance and insurance responsibilities, and provides protection against risk of capital loss due to accidents, mechanical failure, or program cancellation. The contract should include provisions to allow modification of the airplane for instrumentation purposes and to provide the flexibility required for research work. Operation of the airplane from the Monterey Regional Airport

would facilitate access and permit support from the Navy Flying Club for parking space and servicing.

Specialized services and equipment should be provided by contract, at least initially. This will make the instruction and facilities available while the laboratory is being developed. Once areas of greatest need and use have been determined, a decision can be made whether to purchase or continue leasing the necessary equipment.

The contractors currently having the most to offer the NPS Flight Mechanics Laboratory are CALSPAN Corporation and Flight Research, Inc. CALSPAN has been involved in flight research for many years, including flight control development, handling qualities evaluations, and variable stability concepts. This company operates a variable stability Learjet that is used as a teaching and research tool by both USNTPS and USAFTPS. The airplane can simulate the flying qualities of a wide variety of aircraft and demonstrate the effect of individual parameters on dynamic response. Control system characteristics such as friction, freeplay, lead-lag filters, and digital time delay can also be shown. The availability of the Learjet is limited by its use at the test pilot schools. Currently only 30 hours of flight time are uncommitted each year. However, CALSPAN is planning to modify another Learjet in hopes of providing their services to other users. The current cost of the Learjet is approximately $1700/hr (Dry). This fee includes a ground school, text books, and flight instruction.

Flight Research, Inc., is already used by NPS to support the course in flight test evaluation techniques. A fully instrumented Dove airplane is used as a flying laboratory. This company is expanding its facilities and personnel, and may be able to provide additional support. The current cost of the week-long course of instruction is approximately $9000 and includes classroom instruction, data acquisition flights, data acquisition and reduction equipment, and materials. Because of the increased demand for this company's services, longer contract lead times are required to ensure that the necessary support is obtained.

D. INTEGRATION

The flight mechanics laboratory should be able to support all the courses relating to flight mechanics currently offered by the Department of Aeronautics. These courses are:

1. AE 2036 - Performance and Stability.
2. AE 3340 - Dynamic Stability and Vibration.
3. AE 3341 - Aerospace Controls.
4. AE 4323 - Flight Evaluation Techniques.
5. AE 4342 - Advanced Aerospace Controls.

Additionally, the laboratory should facilitate research in all areas of flight mechanics.

In AE 2036, computer instructional devices could be used to present performance and static stability

demonstrations, as well as for projects. The flight demonstration airplane should be used to provide exposure to the laboratory facilities early in the syllabus, to demonstrate static longitudinal stability and center of gravity effects, and as a source of motivation. The simulator should also be introduced early in the program and used as a back-up for the static longitudinal stability flight in the event of inclement weather.

As a part of AE 3340, computer instructional devices could be used to graphically demonstrate dynamic stability and the effects of various aerodynamic parameters on airplane response. The flight demonstration airplane could be used to introduce airplane modes of motion and stability derivatives. A variable stability airplane could further demonstrate the effects of center of gravity and change in derivatives on airplane motion and the pilot's ability to perform closed loop tasks. The flight simulator could again back-up the flight demonstrations as well as for projects.

Computer instructional devices are utilizable in AE 3341 for the development of control systems, as well as for control system demonstrations and projects. Existing software routines for creating root locus, Nyquist, and Bode plots could be incorporated to produce an excellent teaching and research tool. The flight simulator would be particularly effective in this course. Control system demonstrations

and design projects would be much more interesting aNd challenging when combined with the immediate feedback of the simulator.

The flight evaluation course, AE 4323, is not designed to produce test pilots or flight test engineers, so there is no real requirement for students to master "stick and throttle" techniques. Still, as future project managers, students do need to learn the problems and limitations associated with flight test programs. In addition, they need to gain an appreciation for data collection, reduction, and analysis techniques and procedures. Therefore, participation in flight test exercises is essential to this course. The necessary experience could be provided by flights in the demonstration airplane where flight test techniques could be show, data collection practiced, and an appreciation for the constraints of time, fuel, and weather gained firsthand. Computer instructional devices would be very effective in presenting procedures for, and assisting in, data reduction and reporting of results. Flight and data collection techniques could also be demonstrated in the simulator for certain high risk areas not feasible in the available airplanes. Contractors' services should be used to provide a fully instrumented flight laboratory for a final class project as is currently done.

In AE 4342, computer instructional devices and the flight simulator should be used in the same manner as in

AE 3341. A variable stability airplane, provided under contract, should be available for flight demonstration of advanced control system effects and to specifically point out the problems associated with digital flight control systems. A class project could be devised where a control system is designed, tested in the simulator, and then flight tested in the variable stability airplane. This project would expose students to the current techniques of flight control system design, point out the problems associated with control system testing, and show the role of ground and flight simulation in the design and verification process.

E. PROGRESS TO DATE

During the course of this study, many organizations active in the field of flight mechanics were researched. A list of these organizations, including points of contact, is shown in Appendix A. Numerous events have also occurred relating to the study of flight mechanics at NPS. Several of these are worthy of note and will be discussed.

The changes to the Aeronautical Engineering Curricula (610 and 611) have been approved and implemented. A full course in airplane dynamic stability and vibration will now be taught prior to the introduction of control system theory, thus providing the required background.

A demonstration program using the CALSPAN variable stability Learjet was arranged for August, 1984. The purpose of the program was to provide an interim solution to the lack of a flight mechanics laboratory and to determine the benefits and problems associated with the services provided by CALSPAN. An outline of the program and details on classroom instruction and the demonstration flight are shown in Appendix B. Although funding and logistics problems caused the program to be indefinitely postponed, enough support and interest exists to make this a viable concept. A limited demonstration program is now planned for NPS faculty members involved in flight mechanics. The experience that CALSPAN has in the field of flight mechanics and the capabilities of the variable stability Learjet provide excellent potential for use in the NPS Flight Mechanics Laboratory.

Discussions were held with the management of Flight Research, Inc., to determine the company's ability to continue to support NPS and provide additional services. As previously mentioned, increased demand has caused scheduling problems. The company has agreed in concept to provide NPS up to two weeks of availability per year. A formal contract is required to ensure this service will be provided and facilitate planning by both NPS and Flight Research. The company also is expanding its operations, including the development of a variable stability airplane, thus increasing the potential for additional support to NPS.

The flight simulator at USNTPS is now being used as a laboratory exercise to support their classroom instruction. The BASIC language software that was originally used has been replaced by FORTRAN to increase computational speed. USNTPS has provided the Department of Aeronautics with a copy of the BASIC program and documentation, and a copy of the new software, documentation, class notes, and laboratory briefing materials have been requested. A trip is planned in November, 1984, to tour this facility and evaluate the USNTPS and USNA flight simulators. A cooperative program between NPS, USNA, and USNTPS should be expanded to include the development of hardware, software, and instructional techniques for flight simulators.

Much work has gone into researching the various options available for obtainment of a flight demonstration airplane. Most of the effort in this area has been done by CDR. William M. Siegel, Aeronautical Engineering Programs Curricular Officer. An airplane dedicated to flight mechanics instruction and research has consistently appeared in the recent NPS budget requests. The high cost and other problems associated with airplane procurement previously mentioned prompted a more ingenious approach.

In September, 1984, Princeton University announced that it would accept bids for its two variable stability Navion research airplanes. It was the opinion of the NPS

legal officer that, as a government agency, the Department of Aeronautics would be unable to bid directly for these airplanes. Several other organizations, including Mississippi State University and Texas A. & M., did submit bids and have expressed an interest in providing NPS the services of these airplanes under contract. It is anticipated that the Navions will become available in the future and should be considered as a potential asset.

The Drug Enforcement Agency was contacted to determine if airplanes confiscated during drug raids could be obtained. Over 100 airplanes are stored at Homestead Field, Florida, awaiting disposition. In most cases, the airplanes are being held as evidence by the U. S. Attorney's Office and remain in storage several years before being made available to government agencies or publicly auctioned. The poor material condition that results from their storage and the expense involved in their refurbishment limit the potential of this source.

A T-34 airplane has been made available to NPS through the Navy Flying Club organization. Although this airplane does not meet all of the requirements previously mentioned for a flight demonstration airplane, it can be used as an interim solution and would provide a valuable service in helping to define the problems associated with the use of airplanes in flight mechanics. It could serve as a test bed for instrumentation and data acquisition systems, and

would continue to be a valuable asset once a permanent flight demonstration airplane is obtained. Funding from the Naval Air Systems Command in the sum of $50,000 has been identified and would be sufficient to provide the required maintenance, servicing, and storage fees for a year plus the operating expenses necessary to support all of the projected uses of a flight demonstration airplane.

IV. CONCLUSIONS AND RECOMMENDATIONS

It is the general conclusion of this study that a flight mechanics laboratory is essential to the study of flight mechanics at NPS. Theory taught in the classroom must be reinforced by demonstration. "Hands on" experience is needed to clarify principles, promote confidence, and ensure a lasting impression. The laboratory facilities would enhance research and thesis work in the area of flight mechanics, thus adding a new dimension to the Department of Aeronautics. Therefore, a flight mechanics laboratory should be established at NPS as soon as possible.

The proposed laboratory should include the selective use of flight simulators, computer instructional devices, a demonstration airplane, and contracted services. The current shop facilities and staff of technicians can provide most of the necessary support. A ready source of labor and ideas is available through the thesis program. Limited funding has been identified to operate a demonstration airplane and the procurement of additional funding seems promising. Although the Naval Air Systems Command cannot fund educational programs, it is possible to obtain money for research. The staff of USNTPS has been extremely supportive of this study, and future cooperation is anticipated.

At least two billets are needed for military instructors in the Department of Aeronautics to support the flight mechanics laboratory. These officers would be used primarily as demonstration pilots and flight and simulator instructors; they would also be available for classroom instruction. At least one of these instructors should be a graduate of a service test pilot school to ensure the necessary background and expertise required to instruct the course in flight test evaluation, demonstrate the associated techniques inflight, and maintain liaison with USNTPS.

The position of Director, NPS Flight Mechanics Laboratory, should be created and a qualified person hired. This individual would be responsible for developing the laboratory, managing its assets, and ensuring that the laboratory continued to meet the changing requirements of the aerospace engineering curricula. Because of the constraints imposed on faculty members, the director should not be a professor, but rather a civil service employee.

A policy decision is needed regarding the extent of instruction to be provided in the field of rotary wing flight mechanics. The results of this decision will determine if the flight mechanics laboratory should be modified to include helicopters. An approach similar to the one used in this study could be used to determine the changes in the laboratory necessary to support the teaching of rotary wing flight mechanics.

Initially, the flight mechanics laboratory should make extensive use of contractors' services such as those described from CALSPAN and Flight Research. This would provide the necessary instruction while the laboratory facilities are being developed, and at the same time would help define the required specifications of these facilities. Thus, overdesign could be avoided and the value of each component evaluated prior to the investment of time or money in the permanent facility.

APPENDIX A

LIST OF CONTACTS

CALSPAN Corporation Advanced Technology Center P. O. Box 400 Buffalo, N.Y. 14225	Mr. Michael Parrag 1-716-631-6717
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APPENDIX B

STABILITY AND CONTROL DEMONSTRATION PROGRAM

I. INTRODUCTION

A. NPS flight demonstration program for advanced aeronautical engineering graduate students.

B. Program includes ground and flight instruction.

1. Static stability.
2. Dynamic stability.
3. Closed loop flying qualities.
4. Flight control characteristics.
5. Role of simulation in control system design.

C. Contracted services from Calspan Corp.

1. Six (6) hours of ground instruction at NPS.
2. Sixteen (16) 1.5 hour flights (24 hr. total) in variable stability Learjet.

D. Trip will also include tour and briefings at NATC directorates and tenant commands.

II. PERSONNEL

A. Participants will be aeronautical engineering graduate students in the final stages of the NPS syllabus who have completed the flight test evaluation course (AE 4323).

B. List of participants. (Separate sheet)

C. Alternates. (Separate sheet)

III. SCHEDULE

A. Ground instruction: Six 1.0 hr. lectures.

1. 14 Aug
2. 14 Aug
3. 14 Aug
4. 15 Aug
5. 15 Aug
6. 15 Aug

B. Flight instruction: Sixteen 1.5 hr. flights (takeoff times).

1. 1300, 27 Aug
2. 1500, 27 Aug
3. 1300, 28 Aug
4. 1500, 28 Aug
5. 1300, 29 Aug
6. 1500, 29 Aug
7. 1300, 30 Aug
8. 1500, 30 Aug

Make up flight 1300, 31 Aug
Make up flight 1500, 31 Aug

9. 1300, 3 Sep
10. 1500, 3 Sep
11. 1300, 4 Sep
12. 1500, 4 Sep
13. 1300, 5 Sep
14. 1500, 5 Sep
15. 1300, 6 Sep
16. 1500, 6 Sep

Make up flight 1300, 7 Sep
Make up flight 1500, 7 Sep

C. Weekly Plan.

1. Sunday--Travel
2. Monday
   a. am--NATC Welcome Aboard/tour TPS
   b. pm--flights 1, 2
3. Tuesday
   a. am--tour SATD, SETD
   b. pm--flights 3, 4
4. Wednesday
   a. am--tour ASATD, VX-1
   b. pm--flights 5, 6
5. Thursday
   a. am--NATC Staff/tour RWTD
   b. pm--flights 7, 8
6. Friday--Make up flights/travel

D. Summary.

1. 14-15 Aug--Ground instruction
2. 27-31 Aug--Flights 1-8 (Group I)
3. 3-7 Sep--Flights 9-16 (Group II)

IV. FUNDING

A. Flight.

1. Fixed cost	$1700/hr	x 24 hr		=	$40,800
2. Fuel (JP 4)	$1/gal	x 350 gal/hr	x 24 hr		$ 8,400
			sub-total		$49,200

B. Travel.

1.	Perdiem	34 people x 5 days x $50/day	= $ 8,500
2.	Transportation	34 people x $450 (roundtrip)	= $15,300
3.	Rental cars	5 cars x $60/wk	= $ 300
4.	Calspan travel	2 people x $1000	= $ 2,000
		sub-total	$ $26,100

C. Total Program.

1.	Commercial transportation	$75,300
2.	Government transportation	$60,000
3.	Government transportation, meals, and lodging	$54,900

V. ADMIN

A. NPS POC: LCDR K. S. REIGHTLER, AUTOVON 878-2491
B. NATC POC: CDR R. MULLINS, AUTOVON 356-4411
C. Security clearances will be forwarded to NATC by 1 Aug 84.
D. Participating students will be required to complete survey to determine effectiveness of programs.

Classroom Instruction for

Aeronautical Engineering Students

Naval Postgraduate School

I. Introduction.

A. Classroom instruction will be provided by CALSPAN instructor pilots in direct support of flying qualities demonstration flight.

B. Instruction will be given in two, three-hour sessions (six hours total).

C. Purpose of instruction is to review basic stability and control concepts, introduce closed-loop flying qualities, discuss flight control system characteristics, and present an overview of the demonstration flight including normal and emergency procedures.

II. Description of Instruction.

A. Session One

1. Introduction and program overview.

2. Airplane statics and dynamics.

a. Static Stability

(1) General

(2) Longitudinal

(3) Lateral/Directional

b. Dynamic Stability

(1) General

(2) Longitudinal

(3) Lateral/Directional

c. Closed-loop versus Open-loop Characteristics

d. Stability Derivatives (Terms, symbols, description, importance, affected by).

(1) General

(2) Longitudinal

(3) Lateral

(4) Directional

B. Session Two

1. Control Systems

a. General

b. Stick force per

c. Stick Travel

d. Lead and Lag Filters

e. Feedback Control Systems

f. Nonlinear Effects

g. Rate Command Systems

h. Digital Systems (Time Delays)

i. Alternative Controls (Side stick)

j. Miscellaneous Problems

2. Demonstration Flight

a. Overview/Objectives

b. Airplane Description/Cockpit Layout

c. Normal Procedures

d. Emergency Procedures

e. Conduct of Flight

f. Control Input Techniques

g. Data Recording

Flying Qualities Demonstration Flight for

Aeronautical Engineering Students

Naval Postgraduate School

I. Introduction.

A. 1.5 hour flight for two students (one pilot and one FNO) to be flown in CALSPAN VARISTAB LEARJET.

B. Pilot will remain in the right or evaluation seat and NFO will be in the jumpseat. Instructor will remain in left seat throughout flight.

C. Flight is for demonstration only and no "Pilot Evaluation" exercises will be conducted.

D. Briefing will consist of formal classroom session and planeside brief prior to flight. An oral debrief will be conducted following the flight.

II. Objectives.

A. Demonstrate concepts of static and dynamic stability.

B. Identify basic dynamic modes of motion of airplane.

C. Differentiate between open and closed-loop characteristics.

D. Demonstrate effects on flying qualities of varying levels of static longitudinal stability.

E. Demonstrate effect of damping and frequency on short period motion.

F. Identify variety of open-loop motions due to dutch roll mode and relate to pilot's ability to perform various closed loop tasks.

G. Identify roll mode and demonstrate effects of roll mode time constant on pilots ability to control bank angle.

H. Identify spiral mode and show effects of divergence and convergence on pilot's ability to perform tasks and workload.

* I. Demonstrate effects of flight control system.

a. Stick Force Per G

b. Stick Travel

* As time permits.

c. Lead/Lag Prefilters

d. Non-Linearities

e. Rate Command

f. Time Delays

g. Side Stick

III. Flight Content.

A. Define static and dynamic stability using longitudinal motions.

B. Review five dynamic modes.

1. Short Period

2. Long Period

3. Dutch Roll

4. Spiral Mode

5. Roll Mode

C. Demonstrate difference between open-loop vehicle characteristics and closed-loop characteristics.

D. Longitudinal Stability Demonstration.

1. Statically stable airplane.

2. Neutrally stable airplane.

3. Statically unstable airplane.

a. CG between static neutral point and maneuver point.

b. CG at maneuver point.

c. CG aft of maneuver point.

E. Short Period Demonstration.

a. Effect of damping.

b. Effect of frequency.

F. Dutch Roll Demonstration.

   a. Effect of damping

   b. Effect of frequency

   c. Effect of roll to yaw ratio

G. Roll Mode Demonstration.

H. Spiral Mode Demonstration.

   a. Divergent

   b. Convergent

   c. Neutral

* I. Flight Control System Characteristics.

   a. Stick Force Per G (medium, light, heavy)

   b. Stick Motion (fixed stick, large travel, normal)

   c. Lead/Lag Prefilters

   d. Time delay

   e. Nonlinearities (friction, preload, preload plus friction)

   f. Rate command advantages and disadvantages

   g. Side stick demonstration

J. Post Flight Debrief.

   a. Review objectives

   b. Answer questions

   c. Questionnaire to be turned in to Curricular Officer

* As time permits.

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Thesis
R3273 Reightler
c.1 The Naval Postgraduate School flight mechanics laboratory: a feasibility study.